sandstone, conglomerate, shale, limestone, and iron-ore, to a thickness of hundreds and thousands of feet. We are confronted, then, with the problem of a *coal-field*, and bring to our interpretation of it the points already made; viz., that every seam was formed by vegetable growth in a swamp or bog near the sea-level. Subsidence of the coal-forming area must be invoked, and the swamps successively buried under marine sediments.

To see what some of the problems of a coal-field are, let us take a concrete case. The coal-field of eastern Ohio is by far the most orderly field that has ever been described. The regularity and simplicity of its structure make it the type for this whole class of formations. What, then, do we find in this, the simplest and most symmetrical, the least disturbed and complicated, of all known coal-fields? We find a maximum of two thousand feet of strata covering ten thousand square miles. There is a well marked rhythmical order of arrangement of these strata. The three kinds that represent the agency of life are always found in close proximity. Coal standing for the life of the land, limestone for the life of the sea, iron-ore, equally dependent on life for its separation and concentration, but blended with both limestone and coal, these form vital nodes in the series, relatively of small amount, but containing all the economic interest and value. The nodes are separated by the sandstone and shale, which are barren of life, and owe their accumulation to inorganic forces. Measured against the products of life, these inorganic sediments have a thickness of five or ten feet to one. But note, the intervals between the vital nodes are approximately equal. Turning now to the problems presented by this typical field, how can we explain the regularity of these intervals? One suggestion of an explanation is found in that unique contribution to modern science, Croll's 'Climate and time;' viz., that the carboniferous age was a period of high eccentricity, and that the coal-seams were formed during interglacial stages, — an astronomical cause for the recurrence of these cycles of life, that exhibit an almost astronomical rhythm and order, this is a light in a dark place, albeit the light is thus far but a feeble one.

But more important questions yet remain, involving the extent and reach of the several seams, and the laws of growth of the field as a whole. Were the lowest coal-seams formed over the entire area? and may we expect their presence in the central portions of the basin, if we descend deep enough? These questions, and others of like import, must be classed as open, although certain general propositions which it would be a pleasure to expand compel me to believe that they should not be answered in the affirmative.

On the chemical side, there are various unsettled questions pertaining to coal, some of which possess both theoretical and practical interest. But, although they are probably not insoluble, science must sink its roots deeper before it can give us full answers. The microscopic structure of coal is another field in which much remains to be done. It is what has been already done in this direction that gives us our grounds of confidence in regard to the vegetable origin of coal. But the relative importance and distinguishing characters of coals formed of carbonized vegetable tissue, of spores, and of hydrocarbons, are still undetermined.

In conclusion, we may be sure that the problems relating to coal which now rise before us as unfinished, will, sooner or later, find their solution. But when they are solved, will all be known? Nay, verily. Out of these old carboniferous swamps, new questions, larger, deeper, than any we now see, will perpetually arise to stimulate by their discovery, and to reward by their solution, that *love of knowledge for its own sake* which makes us men.

PROCEEDINGS OF THE SECTION OF GEOLOGY AND GEOGRAPHY.

THE section opened with the *éclat* of a masterly address by its chairman, and was continued with lively interest, and a fair attendance, which abated only on the last day of the session. Twenty-seven papers were read, and nearly all of those elicited appreciative and profitable discussion. Debate was never unduly warm, and, though full, rarely wandered from the text. The proper functions of the association were evenly exercised; all ideas were freely criticised; the isolated and retiring student was encouraged; the chronic talker was merciful; and the philosopher, who had evolved from his consciousness a perfect theory of the universe, was persuaded to defer its promulgation. In the distribution of the communications by topics, stratigraphy received the lion's share, rejoicing not only in the leading number of contributions, but in the most important paper of the session. The age of ice claimed less attention than usual, and the mysteries of the archaean were unassayed. The following summary of the proceedings, abandoning the order of sequence of the meeting, gives first place to the earth's crust as a whole, follows with its successive layers from lowest to highest, and closes with volcanism and mineralogy. Geography made no contribution to the programme of the section; but it furnished the only paper accepted by the association for presentation to the general meeting, — a lecture by Capt. E. L. Corthell, on the inter-oceanic problem, the substance of which has already appeared in *Science*.

When, in his celebrated essay, George Darwin deduced from the tidal retardation of the earth's rotation the theorem, that the ellipticity of the terrestrial figure has been diminished throughout geologic time, he omitted to make certain deductions in regard to

the earths' crust, — deductions by no means plain to the physicist who maintains the solidity of the globe, but scarcely avoidable by those who conceive of the solid crust as thin. Two Americans have independently complemented his theory in this respect, and it happened that their arguments were both submitted to the association. Professor Alexander Winchell presented a paper on the sources of trend and crustal surplusage in mountain structure; and, to his great surprise, was followed by the reading of a communication from Mr. William B. Taylor, on a probable cause of the shrinkage of the earth's crust, in which his treatment of surplusage was so closely duplicated that a single abstract may serve for both. Accepting the demonstration by Dutton and Fisher of the quantitative insufficiency of the so-called 'contractional hypothesis' of crust corrugation, and following Darwin in his conclusion that geologic time has witnessed a notable shortening of the equatorial diameter, and a corresponding lengthening of the polar, these gentlemen find in the change of figure a 'surplusage' and consequent 'shrinkage' of the crust. The readjustment of the crust to the less flattened spheroid involved not only a diminution of its area, but the institution of a system of shearing and other strains, calculated to wrinkle the surface in all parts except the polar regions; and to produce, what is actually observed, — a maximum effect within the zone of the equatorial bulge. The remaining half of Professor Winchell's paper, found in the lunar tidal influence an independent reason for the prevailing meridional trend of corrugations. He saw in the lagging of the tide a force tending to slip the tidal crust westward; and this would result, during the ages of crust formation, in an ingrained meridional structure, which would in turn determine the trend of subsequent folds consequent on surplusage.

Three discoveries of fossils were announced in what has been disputed ground at the base of the geologic column. Prof. N. H. Winchell brought from the pipestone-quarry of Minnesota a contorted trilobite of the Paradoxides type, and slabs of sandstone covered with round phosphatic brachiopods referred provisionally to Lingula. From these he inferred the pre-Potsdam and post-Huronian age of a great series of rocks in Minnesota and Wisconsin, including the cupriferous rocks of Lake Superior. Prof. William B. Dwight reported the discovery of a unique Potsdam locality one mile north-west of Vassar college, and in the Wappinger limestone belt. Among the fossils are Lingula primiformis, Lingula minima, Obolella, Conocephalites, and Dicellocephalus. A contribution was made to the veteran Taconic question by Prof. James D. Dana, who exhibited lower Silurian fossils taken at Canaan, N.Y., from the 'sparry limestone' of Emmons, a member of his original Taconic system as first defined by him in 1842. A short discussion followed, in which Professor James Hall said that the existence of Silurian fossils in these rocks was claimed and admitted forty years ago; and Prof. N. H. Winchell argued that Emmons's later use of the title Taconic, in which he applied it to certain rocks in New York, now known to be pre-Silurian, entitle the name to a place in stratigraphic nomenclature.

Professor Edward Orton described the gas and oil wells of north-western Ohio, dwelling especially on their contribution to stratigraphy. The district, as at present known, centres at Findlay, where the first success was achieved. The borings start in the water-lime and Niagara formations, quite below the Berea grit, the only rock from which the geologist would have ventured a year ago to predict a supply of gas. The exploration was incited by superficial indications, — the occurrence of gas in springs, superficial wells, etc., in the vicinity of Findlay. The flow of gas ranges in different wells from 100,000 to 1,200,000 cubic feet per day. The petroleum, which is not afforded in great amount, is black, sulphurous, and of about 35° gravity, — a description applying to all oils from limestones. The descending section, compiled from several well records, includes 275′ of Niagara limestone, 2′ to 6′ of Niagara shale, 30′ to 40′ of calcareous shale (Clinton), 200′ of red shale (Medina), 300′ to 400′ of calcareous shale (recognized by its fossils as Hudson River), 250′ to 275′ of brown shale with fossils (Utica), and 500′ of porous magnesian limestone identified as Trenton. This bears the gas and oil. One matter of note is, that the Hudson River and Utica groups of New York, which in southern Ohio are called 'Cincinnati' because they cannot be separated, are here individually recognized. Another is, that the Cincinnati arch, as illustrated by the attitude of the Trenton, lies farther west in northern Ohio than has been supposed. Its trend is nearly north-south.

The paper which commanded most attention was that of Prof. Henry S. Williams. While no single element of his method is novel, his work must nevertheless be recognized as a new departure; for none of our geologists have heretofore pursued comparative stratigraphy, and the comparative study of faunas, in so close combination, and in such detail. As the importance of the work will command for it, in the pages of *Science*, a fuller analysis than the necessary limits of this report permit, the present notice will be confined to an account of its scope and method. The area studied comprises the southern counties of New York, the adjoining counties of Pennsylvania, and northern Ohio as far as Cleveland. In this area numerous sections were studied, extending from the termination of the Hamilton group in the Genesee shale through the upper Devonian, and terminating upward with the conglomerate underlying the carboniferous. The examination of the sections extended to minute stratigraphic details; and the fossils from each stratum were kept separate, it being found that in rock series, involving alternations of beds lithologically different, there are usually corresponding alternations of distinct faunas. A failure to attend to this principle leads to the mingling of faunas, and consequent misconception; its recognition makes of each fauna an identifiable unit, which can be traced in its geographic distribution, and its successional development. It appears, for example, that the fauna of the black Genesee shale is repeated in every higher black shale of the column; and that, in its successive recur-

rences, it exhibits an orderly series of modifications which are parallel in different sections. Though its record is discontinuous at any one locality, the life of the fauna was continuous somewhere, its distribution at every epoch being determined by ever-shifting physical conditions. Within the field of study are seven distinct faunas: *A*, the middle Devonian, or general Hamilton, fauna; *B*, the fauna of the black shales; *C*, the fauna of the green shales of the Portage group; *D*, the fauna of the brown shales and sandstones of the Chemung group; *E*, the fauna of the Panama conglomerate; *F*, the fauna of the Catskill rocks; *G*, the fauna of the Waverly group. In each of these, except *E* and *F*, from three to seven variations are recognized, which have a successional order, and are designated 'stages.' In presenting his material, Professor Williams defined each stage, and assigned it a symbol, consisting of a letter and a number. A chart exhibited the local stratigraphic columns drawn to scale, and in their proper geographic relations, lithologic distinctions being expressed by colors, and the faunal horizons indicated by their symbols, — a system of graphic presentation which greatly aided the audience in comprehending the author's numerous inductions.

Prof. S. G. Williams reported observations on the shore of Cayuga Lake, at the outlet of Skaneateles Lake, and at Oriskany Falls, leading to the conclusion that lower Helderberg rocks, other than those of the water-lime group, have a greater westward extension in New York than has heretofore been supposed. Prof. James Hall called attention to the uniformity of conditions indicated by the stratigraphic series in central New York, as compared with the varied history deducible from the exposures on the Hudson River; and Prof. J. P. Lesley spoke of the 'infinite variability' of the Oriskany. Pennsylvania contains a thousand miles of its outcrop, in which its thickness oscillates from five hundred feet to nothing at all; and no two sections agree. Mr. A. S. Tiffany gave an account of the corniferous group as it is exhibited in Scott county, Iowa, and in Rock-Island, Ill.; and also of a yellow sandstone at Burlington, Io., which he refers, with doubt, to the Chemung. From the first he reported 246 species of fossils, and from the second 84 species.

The problem of the origin of the paleozoic sediments of Pennsylvania was discussed by Prof. E. W. Claypole. Postulating that the material came from a belt of Archaean rocks now exposed — or known to underlie later formations — in south-eastern Pennsylvania, and adjacent portions of New Jersey and Maryland, he based a computation on the area and known thickness of the sediments, and the area of the assumed district of derivation; and reached the conclusion that the Archaean district had suffered a denudation of several vertical miles. Then, restricting attention to the conglomerates of the paleozoic area, he showed, that, on a moderate estimate, 36,000 square miles of sediment contain an average of thirty feet of vitreous, milky quartz, in the form of pebbles. In the rounding of these by attrition, a still greater quantity of quartz was disposed of; so that a truly immense amount must have existed in the district of denudation. The visible Archaean outcrops contain only a small amount of such quartz, and that is almost confined to a narrow belt of Huronian rocks in Pennsylania. It is probable, therefore, that the Huronian was better represented in the eroded mass of Archaean than it is in the surviving outcrops.

Prof. Lewis E. Hicks described the structure and relation of the Dakota group in Nebraska, maintaining that the actual eastern shore of the Dakota Sea is there recorded. The formation rests on an eroded surface of subcarboniferous limestone, the valleys of which were occupied by bays and gulfs of the Dakota Sea. It is noteworthy that the lines of post-carboniferous drainage were identical with the main lines of modern drainage, though the streams flowed in the opposite direction. It thus happens, that, despite the westerly dip, the eastern boundary of the Dakota has its salients in the east-sloping valleys of the existing topography. The average thickness of the formation is 400 feet: its average dip is six feet to the mile in the direction N. 70° W. It is not entirely, nor even predominantly, composed of sandstone, but contains a large amount of shale, with fire-clays, and, near the top, some lignite.

The first communication on the drift was the opening paper of the session, and introduced to the attention of the section the features of the local geology. As the phenomena Prof. A. Winchell described have long since passed into geologic literature, they need not be recited here; but he touched on a local economic subject which is well worthy of promulgation. Citizens of Ann Arbor have culled from the fields the larger crystalline erratics; and, breaking them into suitable shape, have built of them their finest edifices, public and private. The stones exhibit a variety and individuality which no quarry can rival; but the prevailing flesh-tints and grays blend harmoniously, and the effect is peculiarly agreeable to the eye. Prof. A. H. Worthen described the quaternary deposits of central and southern Illinois, taking for his text the sections afforded by a number of coal-shafts traversing the superficial deposits. The bed-rock surface is diversified by valleys very much as is the drift-surface above, but with a different drainage system. The drift-section is, therefore, variable in thickness, but the sequence of its members is approximately uniform. At bottom is a stratified clay, in part gravelly; and, as judged by its composition, this is derived from the waste or decay of the bed-rock of the immediate vicinity. Then comes a forest-bed — not a universal feature, but so widely spread as to render the well-water of large districts unfit for use. Over this lies a blue and yellow gravelly clay, with glaciated bowlders ranging up to two feet in diameter; then a few feet of loess, and finally a thin bed of fine clay. These deposits do not point to glacial ice alone as an agent. They indicate water also, and the lowest member is either sedimentary or alluvial. Prof. John C. Branner gave an account of the glaciation of the Lackawanna valley, where the same rock-surfaces bear striae in systems diverging from 20° to 40,° and in one instance even 120°. These are

explained by the consideration, that, when the great ice sheet was most extended, its local depth was great as compared to the height of the mountain ridges, and it traversed them obliquely with little or no deflection; but, as its extent and depth diminished, it yielded more and more to the control of the topography. Prof. E. W. Claypole pointed out, that, granting this explanation, a strong argument was afforded against the theory that ice is a great agent of erosion. If the erosion of the later epoch was too feeble to efface the scratches left by the earlier, we cannot reasonably regard the earlier erosion as great. Mr. William McAdams, who last year exhibited bones from the loess at Alton, Ill., announced further discoveries of the same nature, and described the superficial deposits of the region. The list of species now includes mastodon, ox, deer, megalonyx, beaver of several species, gopher, ground-hog, bear, and an animal allied to the wolf.

A phase of post-glacial geology was treated by Mr. G. K. Gilbert, who has recently traced an old shore-line of Lake Ontario half way about its basin. From Hamilton, Can., to Sodus, N.Y., it runs parallel to the modern shore. It then turns southward, and deviously outlines a great bay, studded with islands, which occupied the basin of the Oswego River and its branches from Lyons to Rome, and sent a narrow arm to Cayuga Lake. East of Lake Ontario it is once more parallel to the modern shore. The outlet was then at Rome, and the discharge flowed down the Mohawk valley. The plane of the old water-surface is no longer horizontal, but inclines southward, with an average slope of about four feet to the mile, and westward more gently. At Adams Centre, in Jefferson county, it is 650′ above tide; on the north shore of Oneida Lake, 480′; along the Erie canal south of the lake, 430′; near Rochester, 423′; at Hamilton, 350′. It passes beneath the water of Cayuga Lake near its north end. Subsequent to the epoch of this shore-line, the water-surface of Lake Ontario was depressed below its present, as is shown by many of its bays, which occupy valleys wrought by post-glacial stream erosion. Mr. Gilbert's working hypothesis is, that the shore-mark associated with the Rome outlet records an epoch in which the retreating ice-sheet still occupied the St. Lawrence valley. The northern side of the basin was then relatively depressed; and when the water finally escaped past the ice at the north-east margin of the basin, its surface rapidly fell to a position below the present shore. The existing system of levels has been effected by subsequent crust movements.

A paper by Prof. Frederick D. Chester, on the gabbros and amphibolites of Delaware, was read by title, and will be published in the proceedings. Prof. A. R. Crandall gave an account of some small volcanic dikes, recently discovered in Elliot county, Kentucky. The surrounding strata lie nearly level, and the locality is about ninety miles north-west of the nearest Appalachian dislocation. The dikes do not impress their form on the topography, but have yielded to decay along with the enclosing carboniferous strata. Prof. L. E. Hicks remarked that he had observed on the White River in Nebraska a dike which resembles these, in that it is associated with no disturbance of the sedimentary rocks.

Mr. George F. Kunz briefly described a new mass of meteoric iron from Carlestown, W.Va., and read a series of notes on minerals from new localities, or otherwise interesting. Among them were native antimony from Prince William, N. B.; tourmaline from Rumford, Me.; a pseudomorph of felspar after leucite (?) from Magnet Cove, Ark.; a curious form of beryl from Auburn, Me.; a capped garnet from Raymond in the same state; and a turquoise from New Mexico, artificially stained to produce a favorite blue shade. He described, also, a collection of rough diamonds, temporarily in the possession of Messrs. Tiffany & Co., bringing out especially the fact, that the convex curves of some rough diamonds are not referable to attrition, since only the diamond can wear the diamond, but are made up of crystalline facets. A paper by Dr. T. Sterry Hunt, on the apatite deposits of the Laurentian rocks, was read by abstract.

EDUCATIONAL MUSEUMS OF VERTEBRATES.[1]

FROM what is known of man's present constitution and environment, and from what is commonly believed respecting his future form, condition, and associates, it seems to follow that all kinds and degrees of zoölogical instruction, whether anatomical, histological, physiological, pathological, psychological, or religious, should be based upon some knowledge of vertebrated animals. As aiding to make this knowledge real and lasting, every educational institution, of whatever grade, should have a vertebrate museum.

From many vertebrate collections the average visitor carries away, besides the sense of fatigue, certain impressions which are inadequate or erroneous, or, if correct, uncomplimentary.

The following plans and methods are followed in a preliminary re-arrangement of the vertebrate collections at Cornell university: The exhibition-cases should contain only specimens which can instruct or interest the visitor. Not only should facts be displayed, but fundamental principles should be illustrated. There should not only be special series of embryos, brains, hearts, etc., but such preparations should be associated, to a certain extent, with the animals to which they belong. Preparations illustrating important facts should retain so much of the entire animal as may facilitate recognition and association; when this is inconvenient, the preparation may be accompanied by a figure of the animal. When the relative rank of several forms is well determined, the lower or more generalized should be placed below or at the left, and the higher or more specialized

[1] Abstract of an address delivered before the section of biology of the American association for the advancement of science, at Ann Arbor, Aug. 26, by Dr. BURT G. WILDER of Cornell university, vice-president of the section.